RESEARCH DESIGN: *TITANIC* SITE MAPPING, LIMITED PHOTOGRAMMETRY AND COMPARATIVE TEMPORAL ANALYSIS OF SITE CHANGES, 1985-2020

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Introduction

This proposal focuses on a non-intrusive scientific mission being driven by the ethical standards and guidelines of the archaeological and conservation/preservation fields, assessing issues pertinent to long-term stewardship and management of the wreck site of R.M.S. *Titanic*. There will be no salvage, recovery or intrusive research. The expedition has been made possible by a suddenly available repositioning of an Ocean Infinity deep sea research vessel in the North Atlantic with AUV and ROV capacity in early August. This provides the opportunity for a limited, deployment from August 2-6, 2020 to conduct a non-intrusive, no-impact site assessment, including AUV mapping of the *Titanic* wreck site; selective, no-contact ROV documentation to generate limited photogrammetric models of areas of the wreck site; and measurements of physical, chemical and biological characteristics of the marine environment on and around *Titanic*. The data will be used to measure and assess cultural and environmental changes to the site since its discovery thirty-five years ago in 1985.

The participation of the initial maritime archaeological conservator with extensive experience with historic era metal wrecks, including *Titanic* artifacts from the 1987 French Collection, will also allow for assessment of rates of change and ongoing natural and mechanical processes affecting the wreck site, as well as understanding of site preservation issues. This will help address long term preservation issues concerning the site and wreck that have been publicly discussed and debated for decades. A science-based study that assesses long-term *in situ* preservation has not been prepared to our knowledge, would be timely and in the public interest as indicated in requirements under the Annex and other international and US archaeological standards. This study will specifically draw upon cultural and environmental data sets from 1985, 1986, 2000, 2003, 2004, and 2005. A final report will be prepared as the basis for scientific, peer-reviewed publication in academic journals.

There has been much media discussion and controversy over the status of the wreck's condition and changes to it over time. This includes debate over what some have stated is a likely loss of the wreck's structural integrity within the next decade. This project will provide a scientific assessment of the site through a data-based, non-contact remote sensing assessment of temporal changes through direct observation and comparison as well as sensor assessment from instrumentation mounted on the AUV and ROV to measure dissolved oxygen, turbidity, temperature, nutrients, pH, and inferring current strength from differential movement of the robotic systems. This will be subjected to an extensive assessment of existing environmental data collected by scientists at the time of initial discovery and the first dives in 1986, subsequent dives conducted by Russian scientists and observers, during James Cameron's 2005 mission, and during missions conducted by the

National Oceanic and Atmospheric Administration as well as available publications in peer-reviewed academic journals.

The mission also will bring a maritime archaeological conservator with extensive experience, including *Titanic*, to the site to conduct focused visual assessment and interpretation of the wreck, and the wreck site, with little to no risk to the site. The observations and data will be shared with the National Oceanic and Atmospheric Administration and the United States District Court for the Eastern District of Virginia, with provision made for a live-feed opportunity for the Court, NOAA and general public to inspect the wreck site.

The Site

The wreck of R.M.S. *Titanic* is arguably the best-known shipwreck of the 20th century, an international cultural icon and a site with archaeological, historical, scientific, memorial, aesthetic, and commercial values. One of several deep (> 1 mile) ocean shipwrecks located over the past four decades as technological advances allowed society to rediscover and interact with resources at great depth, *Titanic* has been at the center of numerous expeditions that have both explored and exploited its various values.

The *Titanic* wreck site is approximately 605 km (327 nm) from St. John's Newfoundland, the nearest port. The wreck, as characterized by its detached bow and stern sections, is located at 41°43′57″N 49°56′49″W (bow) and 41°43′35″N 49°56′54″W (stern). *Titanic* rests on a slightly sloping seabed comprised of foraminifera ooze, thin sandy turbidites and muddy beds with mudstone clasts (Savoye, Cochanat and Piper 1990) overlaying dense friable mud, in 3752 to 3796 m (12,310 to 12,453 feet) of water on the eastern North American continental margin, east of Cameron Canyon. The reported characteristic undrained shear strength of sediment (based on a single 1998 coring) is reported at ~ 25kPa within 10–16 m below the seafloor, ~25kPa within 10–16 m below the seafloor (Best et al. 2000). The wreck's environment is characterized by water temperatures of 1–2 °C (34–36 °F), ambient pressure of 372.3 bar (5,399 psi) and varying currents. The major currents affecting the site include the Gulf Stream and the Western Boundary undercurrent; localized current on the site have been recorded up to one knot (Blasco 1994). Other factors influencing the wreck include colonization by marine organisms. Among them is *Halomonas titanicae* strain BH1, a heterotrophic, aerobic marine bacterium (Sánchez-Porro et al. 2013) that is responsible for some of the environmental changes to the steel structure of the wreck (Cullimore and Johnston 2000 and Cullimore, Pellegrino and Johnston 2002).

The wreck site was discovered by a team led by Robert D. Ballard (WHOI) and Jean-Louis Michel (IFREMER) in 1985. Subsequent expeditions have documented and characterized cultural and environmental aspects of the site, beginning with Ballard/WHOI in 1986, and

IFREMER, working with a consortium now known as RMS *Titanic*, Inc. in 1987. Subsequent expeditions by RMS *Titanic*, Inc. took place in 1993, 1994, 1996, 1998, 2000, and 2004. An IMAX filming expedition in 1991 involved a number of partners including AIVL-WHOI. James Cameron made dives and explored the wreck in 1995, 2001 and 2005. NOAA conducted two expeditions to the wreck, one cooperatively with Robert Ballard and the Institute for Exploration (IFE) and the University of Rhode Island, in 2003 and 2004. AIVL WHOI participated in cruises in 1991, 1998, 2001 and 2005 in an attempt to add data to the ongoing WHOI mapping effort.

A 2010 scientific mission, organized by WHOI and RMST, was designed as a scientific expedition with the goal of producing a comprehensive map of the *Titanic* site. WHOI estimated that up to 40% of the approximately six-square mile site had yet to be assessed and was considered to be unknown. Participating in the 2010 mission were the National Oceanic and Atmospheric Administration's Office of National Marine Sanctuaries (NOAA/ONMS), the National Park Service's Submerged Resources Center (NPS/SRC) and the Waitt Institute for Discovery (WID). The WHOI, NOAA/ONMS and NPS/SRC participation in the mission was guided by a letter of intent signed by them with RMST. A 2019 mission by Caladan Oceanic made five submersible dives to the wreck to film it in 4K format with the stated intention of producing photogrammetric models. The status of that data and the results are as yet unknown.

2020 Scientific Mission Objectives

This research mission will fully comply with NOAA's Guidelines for Research and Exploration and Salvage of RMS *Titanic* as published in the *Federal Register* (https://www.federalregister.gov/documents/2000/06/02/00-13791/guidelines-for-research-exploration-and-salvage-of-rms-titanic). However, it should be noted that non-intrusive surveys and mapping is not prohibited by the International Agreement on Titanic or the implementing Act of Congress and thus does not require an authorization. The expedition team is making this submission to indicate its willingness to cooperate with NOAA and others in fulfilling the purpose of the Guidelines, Act and Agreement.

The primary objective is to scientifically assess and document the cultural and environmental change to the site over the past 35 years and providing scientific data to inform the development, if desired, for an in situ site conservation plan that would interpret and protect the site as a non-renewable cultural resource with adherence to ethical guidelines and standards. That process begins by obtaining an updated, detailed, geo-rectified, three-dimensional map of the *Titanic* site from the largest sections of the ship's hull down to the smallest observable artifacts. By measuring a series of physical, chemical and biological properties through video and remote sensing at the site, marine scientists will assist archaeologists in understanding the site formation processes at the

Titanic site, beginning with the physical processes of how the floating ship was displaced to the ocean floor as a shipwreck on April 15, 1912 and its subsequent transformation by natural processes (chemical, biological and mechanical) in the subsequent century since the wrecking event. Temporal changes in the material remains at the site can be determined through analysis to understand the events at the time of the sinking through gross patterning, which is a static interpretation of the events independent of temporal variables.

The research goals/themes for the 2020 mission are:

1. Documenting the distribution of the material remains at the site through sonar mapping;

2. Limited photogrammetric documentation of areas of the wreck site for comparison with data from 1985, 1986, 2001, 2003, 2004 and 2005;

3. Assessing the structural and environmental changes at the site since its discovery in 1985 through comparative assessment of data from previous missions;

4. Making observations on in-situ preservation and assessing potential future changes to the wreck site based on environmental conditions present around the ship.

5. Using the data from this mission to propose a long-term preservation plan for the site, including monitoring, and environmental analysis. For the archaeological and historic preservation community, significant sites should have a comprehensive program of stewardship guided by archaeological and historic preservation standards and ethics.

Distribution:

The documentation of the relative position, orientation, and spatial organization of every component, from the major hull sections to individual artifacts, is a necessary step in creating a basic "map" from which a subsequent assessment of taphonomic processes can be used to identify, separate and characterize the natural from cultural processes that transformed an 888-foot long vessel into a 3 km^2 shipwreck site that has seen seventeen known expeditions dive to the site in submersibles or remotely operated vehicles and the recovery of more than five thousand artifacts. Understanding the spatial extent of the site, with each component (large and small hull sections, machinery, coal both in piles and scattered, and artifacts relating to the ship's passengers and crew) identified on a digital map is the primary step. Significant mapping and visual data from the WHOI work of 1985-1986, and the NOAA expeditions of 2003-2004 exists, as does data from the 2005 Discovery Channel mission. Observational data from 2000 tourism dives also exists and is our possession. Our plan is to integrate these data, effectively allowing for a digital

reconstruction of the site at the time of its 1985 discovery, "pre-disturbance" and then noting changes through a temporal assessment of the site through the lens of data captured on subsequent missions.

Based on observations and discoveries of previous expeditions, it is clear that hull sections and other components are present that can be and have been accurately located in the as-designed blueprints and images of *Titanic*. Those components which can be confidently placed on the ship as it existed prior to the wrecking event, can be "virtually reattached or replaced" in their original location to assist with an understanding of the wrecking and distribution processes. They also provide the means for assessing ongoing change and loss of structure as these measured drawings provide scale that can be used to measure the extent of bacterial colonization, rusticle growth, collapse of structure and loss of structure. Additional environmental measurements collected can be used to determine other drivers of change now and in the future.

To begin understanding longitudinal changes at the site, comparative images of areas previously recorded will be collected through limited photogrammetry to help quantify changes over time. This study intends to provide a visual and temporal comparison of structural changes and site impact with the intent of developing an ability to separate natural and cultural changes. This assessment is important to differentiate between changes inferred as due to the wrecking event damage (collision, sinking, and distribution on the sea bed) and impacts and to the site since that time due to natural and anthropogenic forces.

The key question here is, how has the wreck of *Titanic* responded to the local environment? Are there areas of the wreck that have been preferentially colonized? If so, why? If not, why not? Is there any kind of observable patterning (vertical, horizontal etc.) to any kind of biological or microbiological colonization? If areas are not colonized, are they totally devoid of life? Have other physical or chemical environmental conditions changed (pH, dissolved oxygen, etc.) that could influence wreck degradation rates? Data from previous missions, particularly from the 2003 and 2004 missions, as well as data provided by the Russians from their work on the site will be analyzed by the project's principal investigator for conservation, who will also draw on his data and experience in the conservation of *Titanic* artifacts from the 1987 project and his conservation work on the "Big Piece" from the C deck in 2008. The other aspect is how has the wreck of *Titanic* been changed by anthropogenic interactions? Are intrusive materials from various missions such as fiber-optic cable, salvage and marine debris, or black and greywater discharge over the site having an effect? Is there evidence of changes to the site from impact, landings, or down thrust from manned and remotely operated vehicles?

Operations Plan

The mission will be non-intrusive to not disturb the wreck site. The mission does not plan to come into contact with the wreck, artifacts or seabed. No recovery of samples or artifacts will take place. This will be an instrument-led, distanced remote sensing, mapping and photographic mission. Ocean Infinity, SEARCH, Terra Mare and Stantec operate with established safety protocols for vessel operations on the sea and regularly conduct risk assessments.

The equipment deployed to conduct the overall survey will be one or two HUGIN autonomous underwater vehicles (AUVs) equipped with the latest generation Kongsberg Maritime (KM) HISAS 1032 synthetic aperture sonar (SAS), a KM EM2040 multibeam echosounder, a CathX Hunter Color Stills HD Imaging System, an EdgeTech (ET) DW2-16 sub-bottom profiler, and two possible alternative payloads. The alternative payloads may be interchanged with the HiSAS system to target specific imagery of the wreck site and include a Kraken Robotics MINSAS 120 SAS or an ET2205 Side Scan Sonar (SSS) equipped with three frequencies 75/230/410khz. This technology will yield high resolution sonar imagery and bathymetry that is measurable and repeatable. Surveys covering areas totaling 2.5 by 1.7 km at an optimized elevation (to the specific sensor and varying by line) will provide the data for an acoustic mosaic of a site defined by 2 km by 1.5 km (1.1 by 0.8 nm) boundaries and covering 3.5 km^2 (1.0 nm^2). The principle artifact scatter lies within this area.

Should the project schedule permit, additional AUV run lines will be conducted at a fixed 5m altitude over the wreck's highest elevation to collect color photos. The frame rate will be optimized for 110-120% coverage along track and the line spacing such that 100% coverage across the beam of the wreck is achieved. The vehicles are neutrally balanced with collision avoidance systems that utilize sonar sweeps to automatically correct altitude and reorient the vehicle if it comes too close to the wreck, artifacts or the seabed. The ROV team is highly skilled in deep water wreck observation and provide security human presence and monitoring for the ROV during deployment. The mission is planning to land on, or come into contact with the wreck or the seabed. The mission also will utilize current data provided from the previous missions, in particular from the NOAA/Ballard missions of 2003 and 2004 and Russian data.

After the AUV survey, an ROV will conduct optical imaging of the major components of the wreck site – the bow and stern, as well as large features such as sections of the hull and machinery. To avoid any unintentional contact with *Titanic* the ROV will be a continuous 10 meters away from the hull and all features and structure on the seabed. This is for consistency of mapping and photogrammetry, is based on data from previous missions, and is designed to avoid contact with the wreck. For ROV operations, there will no resting on the hull, or seabed, as other expeditions have done in the past and, again, no recovery and

no salvage of any artifacts. The expedition will also be conducted in accordance with **IMO Circular, COLREG.2/Circ.64** (4 December 2012).

Additionally, the ROV may be outfitted with a laser scanning system and operated over sections of the wreck to acquire high-resolution, 3D point cloud data (co-registered with imagery) of the wreck.

The ROV dives provide an opportunity for live broadcast; the team offers the National Oceanic and Atmospheric Administration and the United States District Court for the Eastern District of Virginia a live-feed opportunity to inspect the wreck site in advance of any other missions to the site by other parties. Separate from that broadcast for the government, the expedition may broadcast one or more live broadcasts for education and interpretation as is done through other telepresence missions. As well, ROV footage may be used for post-mission media purposes.

Time Frame

The current schedule for Ocean Infinity's fleet provides an opportunity to deploy one of their vessels as it transits from the eastern seaboard of the United States to Europe via the North Atlantic in early August 2020. The allocated time available for this mission is four days (96 hours).) currently [tentatively and weather contingent] August 2-6. The vessel, technology, crew and the science team can conduct the mission within this time frame, noting the HUGIN systems are advanced and improved technology that makes the mission possible as the vessel is in transit.

Funding

This mission is funded through the operational budgets of Ocean Infinity and SEARCH, as was the case with the two firms' recent mission to locate, map and conduct a non-intrusive ROV assessment of the wreck of USS *Nevada* (BB-36) in 4746 m of water off Oahu, Hawaii.

Mission Data and Scientific Products

All mission data, including sonar and archives of ROV dives, is logged and curated on Ocean Infinity's FTP site; SEARCH also maintains an Internet and hard-copy archive of data. An initial report on the mission, outlining objectives, methodologies and results will be prepared and will be available to NOAA and the Court. A detailed scientific article will be prepared on the results of the mission; additional articles may be prepared that address specific aspects such as technical, site formation, the wreck as an archaeological site, site preservation, and the assessment of and implications of observed and measured environmental and structural change to the wreck site. These articles will be prepared for submission to academic, peer-reviewed journals such as the *Journal of Maritime*

Archaeology, the *International Journal of Nautical Archaeology*, *Deep-Sea Environments and Ecology*, and others.

Qualifications of the Archaeological/Science Team

CVs for the project principal investigators are attached. Deep-ocean survey, assessment and archaeological work, and *Titanic*-specific experience is noted as follows:

James P. Delgado, Ph.D., RPA

Dr. Delgado's experience as a maritime archaeologist includes work on 19th and 20th century iron and steel wrecks, including deep sites. His telepresence-enabled missions include wrecks in the Gulf of Mexico, the Blake Ridge Wreck in the Atlantic, USS *Independence* and other wrecks in Greater Farallones National Marine Sanctuary, battleship USS *Nevada*, and the Japanese midget submarines sunk off Oahu from the Pearl Harbor attack of 1941. Dr. Delgado was the first non-salvage affiliated archaeologist to dive to *Titanic* (2000) and was Chief Scientist for the last science mission to *Titanic* in 2010 that did the first complete mapping of the wreck site. As the Director of Maritime Heritage in NOAA's Office of National Marine Sanctuaries, Dr. Delgado was the government's maritime heritage policy lead on *Titanic* working with NOAA's Office of General Counsel from 2010 through 2017.

Michael Arbuthnot, M.S., RPA

Mr. Arbuthnot's experience as an archaeologist includes terrestrial and maritime work in shallower water environments, and as the project archaeologist for James Cameron's RMS *Titanic* expedition in 2005 for the *Last Mysteries of the Titanic* (Discovery Channel). That work included extensive documentation and filming of Titanic's exterior and interior. Mr. Arbuthnot has extensive media production experience and in making archaeology and history accessible to public audiences.

Josh Broussard, BSc, MBA - CTO for Ocean Infinity Group

Mr. Broussard has over 16 years' experience working with automated control systems, robotics, and autonomous/unmanned vehicles and 5 years working directly with 6000m rated AUVs and ROVs in deep water search and mapping operations. He led the development of Ocean Infinity's multi-AUV & USV fleet technology and has served as a technical lead for Ocean Infinity's search for MH370, search and location of the Argentine Submarine ARA *San Juan*, the French Submarine *Minerve*, search and location of the *Stellar Daisy*, and Antarctic AUV Operations in the 2019 Weddell Sea Expedition. Prior to joining Ocean Infinity, Mr. Broussard supported onshore and offshore engineering projects in the

energy and marine sectors as a Systems Engineer, Technical Specialist, and Senior Project Manager.

Michael Brennan, Ph.D., RPA

Dr. Brennan joined SEARCH in 2017 with 17 years of experience in maritime archaeology, oceanography, and geochemistry. Dr. Brennan's research includes World War II naval history, remote sensing, geoarchaeology, environmental monitoring of shipwrecks, and bottom trawl fishing damage to shipwreck sites. Prior to joining SEARCH, Dr. Brennan was the expedition leader and archaeologist for Dr. Robert Ballard's Ocean Exploration Trust. His telepresence-enabled missions include wrecks in the Gulf of Mexico, U-166, SS *Robert E. Lee*, USS *Independence* and other wrecks in Greater Farallones National Marine Sanctuary, battleship USS *Nevada*, and numerous ancient shipwrecks in the Black and Mediterranean Seas.

Paul Mardikian, M.S., M.A., FAIC

Mr. Mardikian's experience as a conservator of maritime and terrestrial artifacts and sites spans 30 years and several continents. He has led conservation efforts for numerous maritime archaeological projects including RMS *Titanic,* RMS *Carpathia,* SS *Xantho,* Space Shuttle *Challenger* and Apollo-era Saturn V flown engines, as well as many ancient shipwrecks. He has also directed high-profile projects for the Underwater Archaeology Branch of the United States Navy including CSS *Alabama,* and *H.L Hunley*. Paul's research on the corrosion processes of *Titanic* artifacts and the link to site formation processes goes back to 1990 when he first published on this subject. His research interests include the development of innovative techniques for the analysis and stabilization of complex and large-scale marine artifacts.

Francis Wiese, Ph.D., Environmental Characterization

Dr. Francis Wiese is a Senior Principal within Stantec's Environmental Services Group and serves as Stantec's overall Technical Leader for Marine Science. Francis brings 26 years of experience working in the coastal and marine environment throughout the world, designing, implementing, and managing large inter-disciplinary, multi-institutional science programs in the North Atlantic, North Pacific, Bering Sea, Gulf of Alaska, and the Arctic, and conducting projects in the North Sea, Caribbean, Galapagos, Gulf of Mexico, and the east and west coast of North America. Dr. Wiese has worked for and with academia, government, non-profits and industry, is a technical reviewer for over 20 international journals and serves on a variety of national and international science panels and working groups. He has extensively focused on environmental impacts as a result of anthropogenic stressors,

marine shipping, marine spatial planning, climate change, environmental policy, adaptive management, resiliency, coastal erosion, and system science. He is a prolific public speaker and most of all enjoys thinking outside the box to solve complex real-world issues.

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